

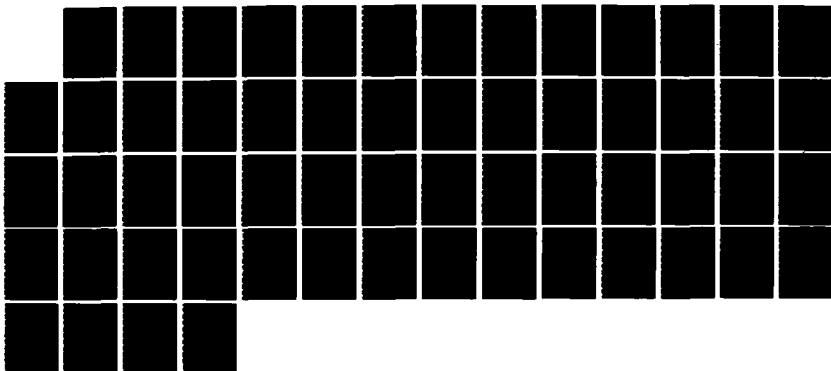
AD-A174 595

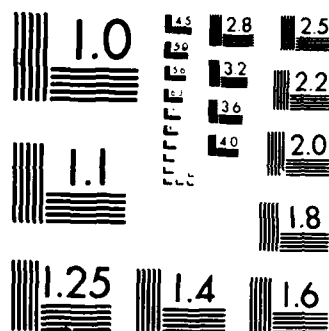
COMPROMISE PROGRAMMING WITHIN ARFCOS: SELECTING AN
OPTIMAL DISTRIBUTION N (U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH SCHOOL OF SYST D G CORBETT
SEP 86 AFIT/GLN/ENS/86S-12 F/G 3/1

1/1

UNCLASSIFIED

NL





1963-A
 NATIONAL BUREAU OF STANDARDS 1963-A

AD-A174 595



COMPROMISE PROGRAMMING WITHIN ARFCOS:
SELECTING AN OPTIMAL DISTRIBUTION
NETWORK FOR THE SOUTHWEST

THESIS

Dwight G. Corbett
Major, USAF

AFIT/GLM/ENS/86S-12

THIS IS THE COPY

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

86 12 02 119

AFIT/GLM/ENS/86 *5-12*

COMPROMISE PROGRAMMING WITHIN ARFCOS:
SELECTING AN OPTIMAL DISTRIBUTION
NETWORK FOR THE SOUTHWEST

THESIS

Dwight G. Corbett
Major, USAF

AFIT/GLM/ENS/86S-12

DTIC
ELECTE
DEC 2 1986
B

Approved for public release; distribution unlimited

The contents of the document are technically accurate, and no sensitive items, detrimental ideas, or deleterious information is contained therein. Furthermore, the views expressed in the document are those of the author and do not necessarily reflect the views of the School of Systems and Logistics, the Air University, the United States Air Force, or the Department of Defense.



Accession For	
NIA	✓
DTIC	
Unrestricted	
Dist	
A-1	

AFTT/GLM/ENS/86S-12

**COMPROMISE PROGRAMMING WITHIN ARFCOS:
SELECTING AN OPTIMAL DISTRIBUTION
NETWORK FOR THE SOUTHWEST**

THESIS

**Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Logistics Management**

**Dwight G. Corbett, B.S.
Major, USAF**

September 1986

Approved for public release; distribution unlimited

Acknowledgments

I would like to extend my sincere appreciation to all those who have, in one way or another, contributed to the completion of this project. A thesis never really has a single author, and there are many people whose names should also appear beside mine on the cover of this thesis. To all of you, I owe a tremendous debt of gratitude.

I thank Major William Rowell, my thesis advisor, for his guidance and constructive criticism. Where my knowledge and experience were weak, his were strong. But mostly, I thank him for his confidence in my abilities and for his patience.

For his support and assistance, I thank Lt Col Larry Fisher, ARFCOS Director of Transportation. His encouragement and willingness to support this research kept me going when I wondered if the end would ever arrive.

To the managers and couriers of ARFCOS, I offer thanks for help that was occasionally above and beyond the call of duty. Without their direction and their patient answers to my endless questions, my models never would have seen the light of day. In particular, I would like to thank Captain Trent Fry, Commander of the Travis ARFCOSTA; Captain Clement Echevarria, Commander of the Kelly ARFCOSTA; CWO-4 Mark Russman, Commander of the San Diego ARFCOSTA; and CWO-4 James Kirby, Jr, Commander of the Los Angeles ARFCOSTA for their hospitality during my fact-finding TDY to their stations.

Major Douglas Steward also deserves a great deal of credit. If not for his suggestion that I consider doing a follow-on to his thesis, I might still be searching for a suitable topic.

A special thanks must go to Captain Earl McNease, my classmate and, most importantly, my friend. His help with the formatting and proofreading of this thesis was almost as valuable as the constant encouragement he tirelessly offered.

For their (usually) unending patience and (always) undying love and support, I thank my wife, Shirley and my sons, Jason, Joshua, and Jonathan. Boys, Daddy's home again!

Finally, I thank God for His strength and perseverance that enabled me to see this project through to its end.

Dwight G. Corbett

Table of Contents

	Page
Preface	ii
List of Tables	vi
Abstract	vii
I. Introduction	1
General Issue	1
Background	3
Specific Problem	4
Research Objective	5
Investigative Questions	5
Scope and Limitations	7
Operational Definitions	7
Summary	9
II. Methodology	10
Introduction	10
The Simulation Process	10
Problem Formulation	11
Model Building	12
Data Acquisition	12
Model Translation	13
Verification	13
Validation	14
Strategic and Tactical Planning	14
Experimentation	15
Analysis of Results	15
Implementation	16
Documentation	16
Compromise Programming	17
Justification for Other Criteria	18
Weighting the Criteria	20
Development of the Attribute Scoring Procedures.	21
Summary	24
III. Analysis of Results	25
Introduction	25
Manning Considerations	25
The Standard Individual Utilization Rate	26
Model Descriptions and Simulation Findings	26
Model 1 Description	26
Simulation Findings	27

Model 2 Description	29
Simulation Findings	30
Model 3 Description	31
Simulation Findings	31
Model 4 Description	32
Simulation Findings	33
Attribute Scoring of the Models	33
Compromise Programming Results	36
Summary	38
IV. Conclusions and Recommendations	40
General Conclusions	40
Recommendations	41
Final Comments	41
Bibliography	43
Vita	44

List of Tables

Table	Page
I. Model 1: Manpower Utilization Rates	29
II. Model 2: Manpower Utilization Rates	30
III. Model 3: Manpower Utilization Rates	32
IV. Model 4: Manpower Utilization Rates	33
V. Attribute Scores for Individual Models	35
VI. Compromise Programming Scores of Individual Models	37

Abstract

The Armed Forces Courier Service (ARFCOS) is the military's distribution network for classified materials. ARFCOS considers available manpower as more binding on future operations than available funding. Therefore, the efficiency of present operations must be improved to reduce manpower requirements while maintaining or improving mission effectiveness. Currently, managers have no specific tools for analyzing alternative distribution networks and comparing them to current systems.

This thesis identified the Southwest as a region in ARFCOS's CONUS operation that would most benefit from this type of comparative analysis. A methodology was proposed using principles of computer simulation and a multiple criteria decision making technique called compromise programming. Models of four alternative distribution networks were built using SLAM II as the implementing language. Simulations were run on a VAX 11/785. All were compared on the basis of security, manpower utilization, economy, and customer service. Then the best network was identified through the application of compromise programming.

This research resulted in the following recommendations. First, current operations by the stations serving the Southwest should be modified to reduce or eliminate the responsibilities of the station at Los Angeles AFS. Next, ARFCOS routes should be examined to ensure maximum use of Consolidated Control Points and Central Servicing Points wherever possible. Finally, the combined capabilities of computerized network simulation and

compromise programming should be fully exploited to enable managers to make sound, supportable evaluations of alternative distribution networks with minimum risk or cost.

COMPROMISE PROGRAMMING WITHIN ARFCOS: SELECTING AN OPTIMAL DISTRIBUTION NETWORK FOR THE SOUTHWEST

I. Introduction

General Issue

The mission of the Armed Forces Courier Service (ARFCOS) is to ensure "the secure and expeditious movement of qualified material which requires controlled handling by courier" (3: 2). ARFCOS is directed by Air Force Regulation 183-2 to give primary consideration to the security of the material, yet they are required to accomplish this mission "as efficiently as practicable" (2: 1-1). There are indications that these twin objectives, security and efficiency, are not being met in some areas of the ARFCOS operation. The Stillwell Commission, a follow-on to the Walker Investigation, discovered that the level of security afforded by the Courier Service is, at times, less than desirable (5). Furthermore, a recent research effort accomplished by two graduates of the Air Force Institute of Technology, Major Douglas Steward and Major Winston Nelms, pointed out the fact that, although the mission is being accomplished, efficiency is not always optimized. Although efficiency usually refers to economy of operation in general, in this case it specifically refers to the assignment and utilization of available personnel (9: 4 - 7). Managers at Headquarters, ARFCOS accept this narrowed concept of efficiency because it is generally acknowledged that manpower requirements will constrain future operations more so than funding requirements (6).

Perhaps nowhere is this need for a better streamlined distribution network more obvious than in the Southwest region of the Continental United States (CONUS), the area served by the Courier Stations (ARFCOSTAs) located at the Naval Supply Center in San Diego, at the Los Angeles Air Force Station, at Travis Air Force Base, and at Kelly Air Force Base. Specifically, the assignments of routes and customers to these four stations and the modes of transportation used to deliver materials to their users appear to be less than optimal (9: 61 – 65, 69 – 71). The managers of ARFCOS are concerned about this situation, and they wish to correct it. Among the possible solutions being considered are: 1) adding another ARFCOSTA at Norton Air Force Base, 2) closing down the Los Angeles ARFCOSTA and redistributing its accounts to the remaining stations, or 3) a combination of the first two actions (5).

Once these alternative solutions have been thoroughly examined, the decision makers at Headquarters, ARFCOS will need to choose the "best" of the alternatives. Their choice will not only be based on the security afforded by the candidate distribution systems and on the number of personnel needed to operate the systems. To a lesser extent, other factors, or criteria, will also need to be considered. Apart from the previously mentioned manpower concerns, which system will cost the least to implement and operate? Which system will provide the best customer service? All of these concerns need to be addressed before the best system can be identified.

Currently ARFCOS does not possess the framework to effectively analyze and compare the performance of alternative distribution systems. This thesis suggests one possible framework for analysis and comparison, and uses it to identify which of the alternatives is superior. It begins by first

modeling each proposed alternative system in a manner similar to that used by Steward and Nelms in their model of the current system. It then performs a comparative analysis of the performance of the various systems in terms of manpower utilization using computer simulation techniques. Finally, it employs a technique of Multiple Criteria Decision Making (MCDM) called Compromise Programming to integrate these simulation results with the other decision criteria in order to identify the best network from the available choices.

As a result of this research, the management of ARFCOS will be better able to decide where to allocate manpower and accounts, and which modes of delivery to use within this vital area of their CONUS operation. The lessons learned from this effort should also provide valuable insight towards solving similar problems throughout ARFCOS.

Background

The Armed Forces Courier Service was created 8 January 1953. It is a tri-service agency under the Joint Chiefs of Staff. Thirty-six ARFCOSTAs are located worldwide to provide secure transportation and delivery of classified material for the Department of Defense (DOD) and other authorized users. The personnel assigned to each station are provided by either the Army, Navy, or Air Force, depending on the station's location and primary customer accounts (4: 2). Of the 36 ARFCOSTAs located worldwide, 15 are within the CONUS. They are at Boston NAS, MA; Charleston AFB, SC; Dover AFB, DE; Jacksonville NAS, FL; McChord AFB, WA; McGuire AFB, NJ; Norfolk NAS, VA; Offutt AFB, NE; Ft. Meade, MD (Hq, ARFCOS); Lowry AFB, CO; Wright-Patterson AFB, OH; Kelly AFB, TX; Los Angeles AFS, CA; Naval Supply Center, San

Diego, CA; and Travis AFB, CA. The last four stations serve the Southwestern United States, and they are the stations that this thesis addresses (2: A-1). The only previous computer simulation of the ARFCOS operation was accomplished in 1985 by Major Douglas Steward and Major Winston Nelms for their Masters Thesis while working as graduate students at the Air Force Institute of Technology. Their goal was "to develop an analytical model (of the current ARFCOSTA CONUS network) to assist the management of the Armed Forces Courier Service in making strategic decisions concerning its complex transportation network" (9: 6). They examined various potential solution approaches including optimization techniques, heuristic techniques, and systems simulation. Because of the dynamic nature of the ARFCOS problem and the inability to conduct experiments on the actual system, they chose system simulation as their method of modeling the CONUS operation. Because of the versatility of its operation, its self-documenting characteristics, its excellent error diagnosis capabilities, and the fact that it is relatively easy to learn and to use, Simulation Language for Alternative Modeling (SLAM II) was chosen as the programming language for model implementation. To maintain programming simplicity, the ARFCOS operation was modeled as a distribution network, the easiest approach for programmers and operators alike to use (9: 11 – 20). These reasons have lost none of their validity since Steward and Nelms did their research, so this current study also used systems simulation, with SLAM II as the implementing language.

Specific Problem

A comprehensive analysis of the viable candidate ARFCOS distribution systems for the Southwestern United States is needed to compare

and contrast the alternative system's operation in terms of the following specific research questions:

1. Which system provides the best security for ARFCOS material?
2. Which system makes the best use of available manpower?
3. Which system costs the least to implement and to operate?
4. Which system provides the best customer service?

Research Objective

The objective of this research effort was to identify, through modeling, computer simulation, and compromise programming, the optimum distribution system from among those proposed for the ARFCOS operation in the Southwestern United States. The results of the computer simulation runs were used to identify the manpower requirements of each alternative system. Each alternative system was also analyzed, compared, and scored for security, economy, and customer service. Then all results were integrated using compromise programming techniques to yield the best alternative.

These research findings will help ARFCOS managers resolve the problems which have been identified in their Southwestern operation. In addition, the procedures developed in the course of this research will provide guidance in handling future problems involving the allocation of manpower and customer accounts to specific courier stations, and the management of customer service requirements throughout ARFCOS.

Investigative Questions

Answers to the following investigative questions were instrumental in the comparative analysis of the candidate systems which provided the answers to the research questions :

1. What percentage of trips from the ARFCOSTA to the servicing point are made by military air transportation? by government-owned ground transportation ? by commercial airline? These answers are relevant to security because DoD-owned transportation assets are preferable over commercial carriers in that they allow the courier more control over his material, while aerial modes are preferable over ground modes (when distances and destinations make air travel practical) because they minimize time-in-transit (4: 9-1,2).
2. What are the manpower requirements of the total system? This refers to the number of couriers and assistant couriers required to operate all ARFCOSTAs in the system under consideration.
3. What percentage of all trips within the system are made by air transportation instead of ground transportation? Air transportation has higher freight costs than ground transportation, and it usually has higher personnel transportation costs also. Therefore, ground transportation might generally be considered more economical than air transportation. (Manhour costs, the other direct aspect of economy, are accounted for in questions 2a and b.)
- 4a. What percentage of customers are serviced "at their doorstep instead of through a CCP or a CSP? This is one indication of customer service.
- b. How frequently is each customer serviced? This aspect of customer service was either maintained or increased within each alternative model.

Scope and Limitations

For the simulation portion of this research, models developed were limited to the Southwestern region of the CONUS. The manpower requirements for each ARFCOSTA within the system were modeled by resource (courier and assistant courier). No attempt was made to model costs other than those implied by the manpower requirements. A minimum of three ARFCOSTAs were required, and a maximum of five were allowable. Customer accounts were assigned to each ARFCOSTA on the basis of proximity to the station. Norton AFB was chosen as the location for the potential new ARFCOSTA because it was a military reservation, which minimized potential start-up, warehousing, and storage costs. In addition, it had ready access to a runway which could support LOGAIR flights, and it was located conveniently near many of the accounts in question (5). Thus, the four proposed systems were as follows:

1. San Diego, Los Angeles AFS, Travis AFB, and Kelly AFB
2. San Diego, Travis AFB, and Kelly AFB
3. San Diego, Norton AFB, Travis AFB, and Kelly AFB
4. San Diego, Los Angeles AFS, Norton AFB, Travis AFB, and Kelly AFB

In calculating the economy scores used in the compromise programming portion of the research, only direct costs were considered. Indirect costs were judged too difficult to quantify because they would primarily come from outside the system. However, in all cases systems were designed to minimize these indirect costs.

Operational Definitions

The following definitions apply throughout this thesis:

The "best" system is that one which most closely approximates the ideal system.

A "Consolidated Control Point" (CCP) is an ARFCOS account designated by one or more other accounts to act as their agent in accepting and entering ARFCOS material.

A "Controlled Servicing Point" (CSP) is a specified location where two or more ARFCOS accounts from different locations agree to meet a courier at a specified time to accept and/or enter ARFCOS material. This arrangement is more secure than a CCP because it allows for a direct transfer of material from the courier to the customer.

"Customer service", as used here, specifically refers to the service frequency and the servicing location provided to a customer account by the serving ARFCOSTA. In designing the alternative networks, maintaining current levels of customer service was secondary to making the operation more efficient.

"Efficiency" refers to the costs required to obtain a fixed goal, in this case, mission accomplishment. These costs are expressed in terms of average manpower utilization and total system manpower requirements.

"Freight charges" reflect the direct unit cost to move ARFCOS material, including the costs of moving it as personal or excess baggage.

(4: 9-2)

The "ideal network" is that one which best satisfies all criteria by which every viable candidate system is compared. These criteria are security, manpower utilization, economy, and customer service. The ideal network is usually a hypothetical composite of available networks, combining the best of all exhibited capabilities in each area to form a single superlative system.

"Manpower costs" are a measure of the amount of time, expressed in manhours, required to conduct the ARFCOS mission.

"Personal transportation costs" refer to the expenses incurred by transporting the personnel assigned to escort ARFCOS material. This includes fares, such as commercial airline tickets, per diem, and non-fare costs, such as lodging or meals, if required (4: 9-2).

A "viable candidate system" is one which meets all the established criteria outlined in the Scope and Limitations paragraph. There are four viable candidate systems, including the current distribution system, which will be modeled and analyzed in the course of this research.

Summary

The Southwest region of the CONUS ARFCOS operation is currently not designed for peak efficiency, in terms of security and manpower utilization. The objective of this research effort was to identify the best distribution network from among four proposed networks, including the network currently being used. The following chapter explains in detail the methodology that was used in accomplishing this objective.

II. Methodology

Introduction

The methodology of a research project serves as a "roadmap" for the researcher and for managers alike. It shows the route to be taken that will eventually lead from the specific research problem, by way of answering the research questions, to the recommended solution. This chapter outlines the procedures that will be used to answer the following research questions:

1. Which system provides the best security for ARFCOS material?
2. Which system makes the best use of available manpower?
3. Which system costs the least to implement and to operate?
4. Which system provides the best customer service?

The methodology chosen for this thesis consisted of two parts. First, the current distribution network and three alternative networks were simulated with computer models. Then, using the analysis of the models and the results of the computer runs as inputs, a Multiple Criteria Decision Making technique called compromise programming was employed to identify the network that most closely approximated the ideal network. In the rest of this chapter, both parts of the methodology are discussed in detail, from generalized procedures long accepted as proper procedure, to specialized techniques developed for the purposes of this research alone.

The Simulation Process

"Successful development of a simulation model consists of beginning with a simple model, which is embellished in an evolutionary fashion to meet problem- solving requirements" (8: 10). This evolutionary process is described by most authorities on the study of simulation as a series of steps,

or stages, leading to the development of a representative model of a system. In his book, Introduction to Simulation and SLAM II, A. Alan B. Pritsker, the developer of SLAM II, lists the following steps:

1. Problem Formulation
2. Model Building
3. Data Acquisition
4. Model Translation
5. Verification
6. Validation
7. Strategic and Tactical Planning
8. Experimentation
9. Analysis of Results
10. Implementation
11. Documentation (8: 10,11)

Each of these steps are explained in the sections that follow as they were accomplished in the development of the alternative distribution system models.

Problem Formulation. For a model to be useful as a tool in analyzing the system which it is designed to simulate, it is extremely important that the problem be clearly stated and understood. In this situation, ARFCOS managers required the tools to evaluate the manpower utilization efficiency of the current distribution system and three alternative distribution systems capable of serving the Southwestern CONUS. The existing models developed by Steward and Nelms did not model the four stations that are currently serving that area together as a single network (9: 28). Therefore, it was necessary to modify the existing models to include all four stations. With this in mind, the four viable candidate systems which had to be modeled consisted of the following networks:

1. San Diego, Los Angeles AFS, Travis AFB, and Kelly AFB
2. San Diego, Travis AFB, and Kelly AFB
3. San Diego, Norton AFB, Travis AFB, and Kelly AFB
4. San Diego, Los Angeles AFS, Norton AFB, Travis AFB, and Kelly AFB

Model Building. Model building is the "abstraction of the system(s) into mathematical-logical relationships in accordance with the problem formulation" (8: 10). In the simulation of the current network model, personnel at each of the four stations involved were questioned, as they were by Steward and Nelms, regarding their route structure, the normal duty day manning procedures, the amount of travel time each leg of every route took, the amount of time spent at each point along every route, their current manning, and other pertinent information (9: 29). For the other three distribution systems, existing customer accounts were allocated to the stations in the proposed network on the basis of proximity. Service times for all accounts in the three alternative models were assumed to be the same as the times used to model the current system. In-transit times for the routes used in the alternative models were either taken from the data used in the current network model if those routes were duplicated, or they were calculated on the following basis. For those routes using ground transportation, times were calculated using an average speed of 40 mph. For those routes using air transportation, times were calculated using an average enroute speed of 200 mph, plus 15 minutes for takeoff and climb to cruising altitude and 15 minutes for descent from altitude and landing.

Data Acquisition. As stated in the previous section, personnel at each of the four stations involved were questioned concerning their route structures, the normal duty day manning procedures, the amount of travel

time each leg of every route took, the amount of time spent at each point along every route, their current manning, and other pertinent information. This knowledge formed the "data base" used in the specification of the models. No other data was needed, so no other data was acquired.

Model Translation. At this point in the simulation process, the actual coding of the model into the SLAM II programming language begins. SLAM II allows the modeler to describe a network as nodes and branches. Typically, branches are used to represent activities and nodes are used to show events. An activity is an effort or a process which occurs over a specified period of time, such as traveling from Point A to Point B or servicing the customers at a particular location. An event, on the other hand, is assumed to be instantaneous. For example, the beginning and the ending of a duty day are two separate events which occur without any passage of time, but which are separated by numerous activities which comprise the duty day. Entities are those objects which pass through the network. These entities, which in this case are vehicles, are assigned attributes such as start times, and they use limited resources such as couriers and assistant couriers, to move throughout the network from start to finish.

Verification. As programs increase in complexity, errors in coding become more likely. The concept of verification is merely the practice of "debugging" the program to insure that it performs properly. Generally, this involves proof-reading the program line-by-line to insure that the code was input without errors, and comparing the results of the runs with the expected results. A little common sense will go a long way when verifying programs, but SLAM II provides some assistance through the use of embedded error-detecting routines (1: 14; 9: 35). All models developed

during the course of this research were thoroughly verified using all of the above techniques.

Validation. The process of validating a model establishes that the model provides an accurate representation of the actual system that it is supposed to simulate (1: 14). Pritsker recommends that the validation task be performed in levels, beginning with data inputs, then proceeding on to the model elements, subsystems, and interface points (8: 12). Since the primary data inputs for the models were in-transit times, based on the experience and/or calculations of the couriers stationed at the ARFCOSTAs, these figures were checked for reasonableness. If these in-transit times appeared reasonable, considering the distances traveled, the transportation mode used, and the likely driving conditions (such as high-density traffic), they were assumed to be valid. Next, the validation of the final three levels was simplified as follows. In the case of model #1, the current system, the model's performance was validated by comparing its output with estimates obtained from the actual ARFCOSTAs. For all other models, results of simulation runs were compared to expected results. These expected results were based on the judgments of experienced ARFCOS personnel from both Headquarters and from the stations in the field. Again, a little common sense went a long way. In case of significant discrepancies, the situation was closely examined to determine the reasons for the differences.

Strategic and Tactical Planning. Strategic and tactical planning relate to the design of experiments. The first, strategic planning, seeks to insure that through proper design, the experiment will yield the information needed to answer the research questions. Tactical planning is concerned with the efficiency of the experimental process, how to get the most information out of the experimental data. In the case of this research, tactical planning

meant insuring that sufficient trial runs were accomplished to accurately estimate the performance of the network being simulated without going overboard and making more runs than necessary (10: 30,31; 8: 13).

The strategic plan was to run each of the four models to obtain average manpower utilization rates. This data was then manipulated to obtain the desired information: the manpower requirements, which would reflect the relative efficiency of each alternative network. The tactical plan was to run each model one time because multiple runs were unnecessary. Since the in-transit times were modeled as fixed intervals instead of random variables, the results of the first run would be identical to all runs that might follow, making additional runs a waste of computer time.

Experimentation. Experimentation involves the implementation of both the strategic and tactical plans. The models were run and the output information was collected. The runs were accomplished on the VAX 11/785 because of this system's capability to handle relatively large models, and because of the availability of a SLAM II compiler.

Analysis of Results. The results of the simulation runs were analyzed separately and then compared with each other in order to draw conclusions concerning the relative performance of the simulated networks. Analysis consisted of computing the value for the Total Manpower Requirements of each system. This was accomplished by obtaining the value for the average utilization rate of each resource (SD09, SD14, LA09, TR14, etc.) used by the system. This figure was identified as "AVERAGE UTIL" in the Slam II Summary Report. It was then divided by the Standard Individual Utilization Rate of 0.19. (For derivation of the Standard Individual Utilization Rate, see Manning Considerations in Chapter III.) The resulting figures for each resource were then summed to obtain the total requirement for the system.

$$M_i = \sum_{j=1}^n (u_j / 0.19) \quad (1)$$

where

- i = the model #
- j = the resource, such as SD09
- n = the number of different types of resources in a system
- M_i = the total manpower requirement for all stations in the model
- u_j = the AVERAGE UTIL figure for a particular resource,
taken from the model output

Once these calculations were completed for all models, the results were then ready to be combined with other observations on security, economy, and customer service for further analysis through compromise programming.

Implementation. Implementation of any recommendations will be at the discretion of the managers at Hq, ARFCOS. The models developed should improve the capabilities of these managers to make informed decisions concerning ARFCOSTA locations, customer account assignments, and transportation mode selections that will optimize the distribution operation in the Southwest, and throughout ARFCOS.

Documentation. Documentation is necessary to ensure that both model designers and users understand how the program operates. This aids programmers during verification and validation, and it gives the users confidence in the program so that they can make decisions based on the analysis of the output. It also facilitates future modifications to the model parameters and/or structure by the same or a different analyst. Adequate documentation also requires that results and analysis be reported completely, clearly, and concisely so that decision makers can review the work from start

to finish (1: 14,15). The simulation programs developed as a result of this research made full use of Slam II's self-documenting features, and the results and analysis of all simulation runs are fully described in Chapter III.

Compromise Programming

With every step mankind makes in the name of progress, it becomes increasingly difficult to view the world in only one dimension, to judge based on a single attribute. Indeed, very few decisions are ever made based on one attribute alone. Managers and decision makers must be able to "balance a variety of needs and goals" (11: 1). For this reason, specialists in operations research have developed various Multiple Criteria Decision Making (MCDM) techniques. These techniques enable the decision maker to choose an alternative which best satisfies the goals, objectives, constraints, or criteria of a particular situation. Compromise programming is a relatively recent development of this sort of methodology.

Compromise is a natural and necessary outcome of making decisions based on multiple, often conflicting objectives or criteria. Ideally, the decision maker would like to completely satisfy all criteria, but that may be impossible in a practical sense. It becomes necessary to "compromise" some or all criteria to some degree while attempting to emulate the ideal solution as closely as possible. Compromise programming attempts to evaluate various solutions based on their mathematical difference, or "distance", from the ideal solution. The best solution is the one which either minimizes this distance from the ideal solution, or which maximizes the distance from the "anti-ideal" solution (11: 315). By definition, the ideal solution is usually a hypothetical composite of the available solutions, combining the best of all exhibited capabilities to form a single superlative solution.

Developed from the formula for determining the Euclidian distance between two points, the formula for calculating the distance from the ideal alternative is:

$$d_p = \left[\sum_{i=1}^n \left\{ w_i (y_i^* - y_i) / (y_i^* - y_{*i}) \right\}^p \right]^{1/p} \quad (2)$$

where

- d_p = the normalized distance
- y_i = the actual score for attribute y_i
- y_i^* = the "ideal", the best score for attribute y_i
- y_{*i} = the "anti-ideal", the worst score for attribute y_i
- w_i = subjective weight, or importance, assigned to attribute y_i
- p = subjective measure of the decision maker's decision policy
- n = the number of measures of attribute y_i

and where $w_i > 0$ and p ranges from 1 to ∞ . The value for p is indicative of the decision maker's policy concerning the relative contribution of individual deviations to the total. A larger p gives greater emphasis to the larger deviations in forming the total value for d_p , to the extent that $p = 1$ implies the "longest" distance between the two points because all deviations are equally considered. However, at $p = \infty$, the largest of the deviations dominates the total completely (11: 317).

Justification for Other Criteria. The information obtained from the computer simulations is useful in making comparisons based on the single characteristic of manpower utilization rates. However, as might be expected from the preceding discussion, decisions are never quite that simple. For instance, the ARFCOS Manual requires that security and economy, or cost-effectiveness, be considered in sequence when determining the mode and/or

route of transportation to be used in moving ARFCOS material. The Manual further defines security as consisting of the following factors, again given in descending order of importance:

1. The courier should be able to maintain control of ARFCOS material through either personal possession of the material, continuous physical surveillance of the material, or actual proximity to the material. For instance, if traveling by commercial airline, the material can be stored during flight in the cargo hold while the courier sits with the other passengers. But during loading and unloading of the cargo hold, the courier must be on the flight line in a position to closely observe all activities and ensure the security of the ARFCOS material.
2. Whenever possible, DoD transportation assets should be used to move ARFCOS material, with commercial carriers controlled by U.S. interests as the second choice.
3. Handling of ARFCOS material should be minimized when designing routes and schedules. This means minimizing changes in modes, number of ARFCOSTAs involved, and the need to physically handle material.
4. Transportation routes and modes should be chosen to minimize the time-in-transit between the originator and the addressee.
5. Transportation routes and modes should also ensure that areas and situations identified by counterintelligence sources as potential hostile threats are avoided (4: 9-1,2).

In situations where the security considerations of rival routes and/or modes are judged equal, the most cost-effective alternative should be chosen.

The following economic factors should be considered when evaluating cost-effectiveness:

1. Direct costs, such as freight charges, personnel transportation costs, and manpower costs, should be minimized.
2. Indirect costs, such as the impact of candidate options on other existing ARFCOS operations, and opportunity costs should also be kept to a minimum (4:9-2,3). As stated in Chapter I, these costs were not addressed by this thesis because they originated from outside the system.

One final characteristic of an alternative, not mentioned in any regulation, is the degree of customer service afforded by that alternative. For instance, a station provides greater customer service if it delivers material directly to the customer's door rather than making the customer come to a central servicing point, or if it delivers material weekly instead of every other week. However, since improving customer service can greatly increase operating costs and manpower requirements, this is the least important of the considerations.

Weighting the Criteria. Now that the characteristics which were used as the basis for comparing the alternatives have been identified, a weight must be assigned to each attribute as a measure of its importance to this decision. These weights are purely subjective, but to be valid they must accurately reflect the concerns of the decision maker. The following weights, w_i , were provided by LtCol Fisher, the ARFCOS Director of Transportation (7):

$$\begin{aligned}\text{Security, } w_1 &= 0.4 \\ \text{Manpower Utilization, } w_2 &= 0.3 \\ \text{Economy, } w_3 &= 0.2\end{aligned}$$

$$\begin{aligned}\text{Customer Service, } w_4 &= \underline{0.1} \\ \text{Total} &= 1.0\end{aligned}$$

Development of the Attribute Scoring Procedures. The models were developed. The criteria by which they were to be evaluated were selected and assigned appropriate weights. The last step, prior to accomplishing the mathematics of the compromise programming, was to score each of the models according to the individual criteria. These scores, y_i , were calculated from the information contained in the answers to the investigative questions, and in all cases the scores were normalized to prevent distortion of the data. Because of this normalization process, the range of possible values for each score was from 0.0 to 1.0.

Each system received a score for the level of security it achieved, relative to the other systems. This score was based on the extent to which the system used the most secure modes of transportation, as defined by the ARFCOS Manual (4: 9-1). Military and contract air transportation offer the greatest security because they give the courier the greatest amount of control over his material, and because they minimize the time-in-transit. Ground modes of transportation are much slower on all but the shortest trips, but they also offer a very high degree of control over the material. Commercial air transportation offers the least control. Therefore, trips by military or contract air were assigned a weight of 1.0, trips by ground were given a weight of 0.5, and trips by commercial air transport were weighted 0.0. The formula used to calculate the normalized score was therefore:

$$y_1 = \{ (1.0)(n_{\text{air}}) + (0.5)(n_{\text{grd}}) + (0.0)(n_{\text{comm}}) \} / n_{\text{tot}} \quad (3)$$

where

n_{air} = number of trips using military or contract air transportation
 n_{grd} = number of trips using ground transportation
 n_{comm} = number of trips using commercial air transportation
 n_{tot} = total number of trips

Thus, if a system used military or contract air transportation for all of its trips, it received a score of 1.0. Likewise, if a system used commercial air transportation for all of its trips, it received a score of 0.0.

The scores for manpower requirements were calculated using the values for Total Manpower Required that were obtained from the analysis of the results of the simulation runs. To determine the potential savings in manpower relative to the requirements of the current system, the total required by the alternate model was subtracted from the "anti-ideal," the largest total required by any of the models. This quantity was then divided by the difference between the ideal and the anti-ideal. Although it may not seem realistic to speak in terms of a manpower requirement of, for example, 4.5 couriers, this figure is based on the average number of manhours that a courier would normally be expected to work. Therefore, the use of partial couriers is necessary to score relative differences in manning requirements of the different systems. (Again, refer to Manning Considerations in Chapter III.) Thus, the formula used to calculate the manpower utilization score was:

$$y_2 = (m_* - m_j) / (m_* - m^*) \quad (4)$$

where

m_j = the manpower requirements for model being evaluated
 m^* = the "ideal", the lowest manpower requirements among the four models

m_* = the "anti-ideal", the highest manpower requirements among the four models

The model with the lowest total manpower requirement exhibited the best manpower utilization, and therefore received a score of 1.0, while the model with the highest total manpower requirement scored 0.0.

Based on interviews with both Hq, ARFCOS and with station personnel, contracted air transportation, though more secure and speedy than ground transportation, is also much more expensive. The formula for calculating the score for economy was based upon that simple principle. To obtain the score, the number of trips by air within a system was subtracted from the total number of trips made by stations within that system. This difference was then divided by the total number of trips to obtain a normalized score. The formula is as follows:

$$y_3 = (n_{tot} - n_{air})/n_{tot} \quad (5)$$

where

n_{air} = the number of trips made using air transportation

n_{tot} = the total number of trips made by all transportation modes

Therefore, if a model was to use air transportation for all of its trips, its economy score would be 0.0, while a system using ground transportation exclusively would receive a score of 1.0.

Customer service was the one aspect of ARFCOS operations that showed the lowest degree of standardization. Many stations service almost all of their accounts through consolidated control points (CCP) or controlled servicing points (CSP). However, some stations, because of the type of accounts they serve and/or their proximity to their accounts, are able to

service those accounts door-to-door. These stations are providing those accounts with a higher level of customer service. The formula used to calculate the score for customer service reflects this higher level.

$$y_4 = 1 - \{(a_{tot} - a_{door})/a_{tot}\} \quad (6)$$

where

a_{door} = the number of accounts serviced "door-to-door"

a_{tot} = the total number of accounts served by the model

A system could receive a customer service score of 1.0 by serving all of its accounts door-to-door. However, serving all accounts through a CCP or a CSP resulted in a score of 0.0 for customer service.

Summary

This thesis used a two-part methodology. The first part consisted of the simulation process, in which the four proposed networks were modeled as distribution networks, and the models were run on a VAX 11/785 computer. The second part involved the use of Compromise Programming, a relatively recently developed technique of Multiple Criteria Decision Making that integrates the values of the various criteria (security, manpower, economy, and customer service) into a single measure for the benefit of the decision maker. The resultant analysis enabled the selection of one of the networks as the best of the available options. The next chapter describes the analysis of the models and their output, and attempts to determine the answers to the research questions in order to aid in the resolution of the management problem.

III. Analysis of Results

Introduction

This chapter begins with a discussion of ARFCOSTA manning considerations and the development of the Standard Individual Utilization Factor. Then a brief description of the models is presented, along with the findings resulting from their simulation runs. Following a concise review of the attribute scoring procedures, the scores for each of the models are presented. Finally, the results of the Compromise Programming analysis are given and the best alternative is identified.

Manning Considerations

Each ARFCOSTA is manned by couriers (E-7's and above, referred to as Form 9's because of the form number of their ARFCOS identification cards) and assistant couriers (E-6's or below, referred to as Form 14's). Only Form 9's are allowed to receive or dispatch ARFCOS material. Form 14's serve as administrative specialists, vault workers, drivers, and guards. Form 9's may perform Form 14 duties, but Form 14's may not perform Form 9 duties. The commander of the ARFCOSTA, of course, is a Form 9.

Trip manning varies according to the type of transportation used, the length of the trip, and the number of service points involved. Those trips using ground transportation require a minimum of one courier and one assistant courier to serve as driver and assist with loading, unloading, and other details. If the trip involves an overnight stay, a third person (courier or assistant courier) may be assigned to provide additional assistance. Trips using air transportation may require only a single courier to accompany the material, if all of the material is being delivered to the same destination.

However, if multiple destinations are being serviced, a minimum of two personnel (a courier and an assistant courier) are required. This allows the courier to service each account while the assistant courier safeguards the remaining material (9: 44).

The Standard Individual Utilization Rate

In their research, Steward and Nelms developed the concept of the Standard Individual Utilization Rate. By their reasoning, of the twenty-one possible shifts per week (three 8-hour shifts per day), an individual could realistically be expected to work an average of five shifts. This yields a utilization rate of 0.238 for that individual ($5/21 = 0.238$). When one month of annual leave is accounted for, this individual utilization rate drops to approximately 0.194. Training, sickness, and personal problems are also expected to reduce this rate somewhat. Therefore, in the absence of an acceptable existing standard, Steward and Nelms proposed an individual utilization rate of 0.19 as the standard to be used for comparison purposes. This standard rate is also used to make estimates of required station manning by dividing the average utilization rate, as reported by the simulation output, by 0.19 (9: 44,45).

Model Descriptions and Simulation Findings

Model 1 Description. This model represents the current network as it now operates in the Southwest, with stations located at San Diego, Los Angeles AFS, Travis AFB, and Kelly AFB. Route descriptions and account information were obtained through direct interviews with station personnel and through the monthly activity reports provided by each station.

The San Diego station operates with 5 couriers and 5 assistant couriers assigned. A total of 370 accounts are serviced monthly through 24

scheduled trips. Four accounts are serviced door-to-door, and the remaining 366 accounts are serviced via a CCP or a CSP. Of the 24 scheduled trips, 8 are via QUICKTRANS, the Navy's equivalent to the Air Force's LOGAIR. The other 16 trips use ground transportation.

The Los Angeles station is manned by 4 couriers and 3 assistant couriers. A total of 342 accounts are serviced monthly through 16 scheduled trips, all of which are made using ground transportation. Of the 342 accounts, 85 are serviced door-to-door and the remaining 257 are serviced through a CCP or a CSP.

The Travis station has 12 couriers and 9 assistant couriers assigned. They service 396 accounts monthly with 25 scheduled trips. Eight trips use commercial air, eight use ground transportation, 5 use contract air transportation, and the remaining 4 use the Navy's QUICKTRANS flights. All 396 accounts are serviced through either a CCP or a CSP.

The Kelly station is manned by 13 couriers and 9 assistant couriers. A total of 605 accounts are serviced monthly through 19 scheduled trips. One trip is by ground transportation. Four trips use commercial air transportation. Six trips utilize LOGAIR, and the remaining 8 are by contract air transportation. All 605 accounts are serviced through either a CCP or a CSP.

Simulation Findings. The results of the computer runs from the model simulations are displayed in Tables I through IV. The columns entitled Resource Name and Personnel Assigned are self-explanatory. Average Utilization, which is an estimate of the average quantity of a particular resource that a model uses at any one time, was taken directly off the SLAM II Summary Report. Maximum Utilization, on the other hand, reflects the most of a particular resource that a model uses throughout its

operation. If this figure equals the Personnel Assigned, a potential problem could arise which would exceed the capacity of the model. For instance, an unscheduled tasking could occur when the required resource was being completely utilized by the system, resulting in the system being unable to perform the special mission until the resource became available. The Individual Utility Rate is calculated by dividing the Average Utilization by the Personnel Assigned. If this value exceeds the standard individual utilization rate of 0.190, it is likely that either the resource is not being utilized in an efficient manner, or that the applicable station is undermanned in that resource. However, a value significantly less than the standard rate does not necessarily indicate either efficient resource management or an overmanned station. A low value may be the result of a necessary capacity to absorb a high number of "specials," which are unscheduled, usually short-notice taskings. Another reason for a low value could be inadequate detail in the model itself. The remaining column, Personnel Required, represents the manpower needed to achieve the standard individual utilization rate. The value is obtained by dividing the Average Utilization by the standard rate. The Total Manpower required for the whole system is merely the sum of all the individual resource requirements. It is this figure which is used as a relative measure of the manpower efficiency of competing systems, and which is used in the computation of the model score for manpower utilization.

Table I gives the findings of the Model 1 simulation run. The results of this simulation indicate that the stations at Travis AFB and at Los Angeles AFS are operating at or very near the standard rate, which would indicate that they are sufficiently manned in all resources for their current system of operation. The Kelly AFB station and the San Diego station are the only ones

which exceed the 0.19 standard utilization rate, indicating a need to either add more of the resources that appear overworked, or to restructure their operation in order to make it more efficient. For the purpose of scoring the attribute y_2 , this first model has a total manpower requirement of 61.73.

Table I
Model 1: Manpower Utilization Rates

<u>Resource Name</u>	<u>Personnel Assigned</u>	<u>Personnel Required</u>	<u>Average Utilization</u>	<u>Maximum Utilization</u>	<u>Individual Utility Rate</u>
SD09	5	5.42	1.03	4	0.206
SD14	5	6.00	1.14	5	0.228
KE09	13	12.47	2.37	8	0.182
KE14	9	10.63	2.02	7	0.224
TR09	12	12.00	2.28	6	0.190
TR14	9	8.53	1.62	5	0.180
LA09	4	4.00	0.76	3	0.190
LA14	<u>3</u>	<u>2.68</u>	0.51	2	0.170
Totals	60	61.73			

Model 2 Description. This model simulated using three stations to serve the Southwest, closing the facility at Los Angeles AFS. The accounts previously served by Los Angeles were assigned to San Diego on the basis of proximity to the station and to existing routes. The Kelly station, which already flies a LOGAIR route that lands at Davis-Monthan AFB and Luke AFB, assumed the Luke, Scottsdale/Motorola, Davis-Monthan, and Ft. Hauchuca accounts previously assigned to San Diego. These additional accounts increased the Kelly's total volume to 675 separate accounts, while the San Diego total volume was increased to 642. To ease the task of

accepting this large increase in activity, door-to-door service was halted and all accounts were served through CCPs and CSPs. San Diego's available manpower was also increased by 2, to 6 couriers and 6 assistant couriers, to help manage the new trips. Kelly also picked up 2 new assistant couriers to ease their shortage. The tasking for the Travis station remained unchanged. The breakdown of routes and transportation modes remained the same as before for the Kelly station, but San Diego picked up 6 more trips using ground transportation and 2 more trips using contract air transportation.

Simulation Findings. The findings of the simulation run of Model 2 are summarized in Table II below.

Table II
Model 2: Manpower Utilization Rates

<u>Resource Name</u>	<u>Personnel Assigned</u>	<u>Personnel Required</u>	<u>Average Utilization</u>	<u>Maximum Utilization</u>	<u>Individual Utility Rate</u>
SD09	6	5.37	1.02	5	0.170
SD14	6	5.84	1.11	5	0.185
KE09	13	12.53	2.38	8	0.183
KE14	11	10.68	2.03	7	0.185
TR09	12	12.00	2.28	6	0.190
TR14	<u>9</u>	<u>8.53</u>	1.62	5	0.180
Totals	57	54.95			

This model was much more efficient than the first model. Even though San Diego increased their number of accounts almost two-fold, they were able to realign their trips to accomplish the mission. The additional manpower gained by the San Diego and Kelly stations enabled them to lower

their individual utilization rates to below the standard rate, and the overall system was still manned by 3 fewer resources than the first model. The total manpower requirement of 54.95 for this model indicates a much more efficient system. It accomplished this feat by relying on contract air transportation. However, the ceasing of all door-to-door service probably managed to upset those customers who lost that added service.

Model 3 Description. The third model simulated a four-station system with ARFCOSTAs at San Diego, Norton AFB, Travis AFB, and Kelly AFB. San Diego acquired the accounts from Seal Beach, Long Beach, the Long Beach Naval Shipyards, the accounts that were previously served over-the-counter by Los Angeles, plus they gained a road trip to Norton. The new Norton station was given San Diego's accounts in MCAS Yuma, NAS El Centro, Yuma, and Calexico, plus the remainder of the Los Angeles accounts. Kelly retained San Diego's Phoenix and Tuscon accounts, as they did in the second model, and they also retained the two new assistant couriers. However, San Diego was maintained at 5 couriers and 5 assistant couriers. Again, the Travis operation was not altered. The new account totals became 395 for San Diego, of which 10 were serviced door-to-door, and 248 for Norton, with 75 customers receiving door-to-door service. San Diego still accomplished 24 scheduled trips, with 8 by QUICKTRANS and 16 using ground transportation. Norton had 12 scheduled trips, 2 using contract air transportation and 10 using ground transportation.

Simulation Findings. This third model represented a slight improvement over the first model. As the findings recorded in Table III show, all resources were used at or near the standard rate. However, the cost of achieving this improvement was an increase in personnel assigned to the system from 60 to 62. Furthermore, this model did not appear to be as

Table III
Model 3: Manpower Utilization Rates

<u>Resource Name</u>	<u>Personnel Assigned</u>	<u>Personnel Required</u>	<u>Average Utilization</u>	<u>Maximum Utilization</u>	<u>Individual Utility Rate</u>
SD09	5	4.63	0.88	4	0.176
SD14	5	5.26	1.00	5	0.200
KE09	13	12.53	2.38	8	0.183
KE14	11	10.68	2.03	7	0.185
TR09	12	12.00	2.28	6	0.190
TR14	9	8.53	1.62	5	0.180
NO09	4	3.58	0.68	3	0.170
NO14	<u>3</u>	<u>2.26</u>	0.43	2	0.143
Totals	62	59.47			

efficient as the second model, which equaled or bettered this model's performance on nearly all fronts. The total manpower requirement of the model was 59.47, better than that of the first model but not as efficient as the second.

Model 4 Description. The fourth model presented the system as a network of 5 stations. Kelly and Travis were unchanged from the previous two models. Los Angeles retained 213 accounts, of which 47 were serviced door-to-door, and all were served by one of 10 trips using ground transportation. Norton had 182 accounts assigned, with 38 getting door-to-door service. Air transportation was used for 2 of Norton's 10 scheduled monthly trips. The others used ground modes of transportation. San Diego served the remaining 317 accounts with 8 trips using air transportation, 10 ground trips, and no door-to-door service.

Simulation Findings. Although no station received additional manpower, the lesser volume caused each of the three Southern California stations to experience significantly lowered individual utilization rates. None of the stations experienced a shortage of available resources. However, the additional requirement to staff an extra station eventually took its toll. The total manpower requirement for this system was 63.22 , making it the system with the highest total requirements of all the systems modeled. See Table IV for detailed findings.

Table IV
Model 4: Manpower Utilization Rates

<u>Resource Name</u>	<u>Personnel Assigned</u>	<u>Personnel Required</u>	<u>Average Utilization</u>	<u>Maximum Utilization</u>	<u>Individual Utility Rate</u>
SD09	5	4.32	0.82	4	0.164
SD14	5	4.68	0.89	4	0.178
KE09	13	12.53	2.38	8	0.183
KE14	11	10.68	2.03	7	0.185
TR09	12	12.00	2.28	6	0.190
TR14	9	8.53	1.62	5	0.180
LA09	4	3.32	0.63	3	0.158
LA14	3	1.95	0.37	2	0.123
NO09	4	3.26	0.62	3	0.155
NO14	<u>3</u>	<u>1.95</u>	0.37	2	0.123
Totals	67	63.22			

Attribute Scoring of the Models

Each of the models was scored based on how well it satisfied the criteria of security, manpower utilization, economy, and customer service.

Procedures for calculating these scores were explained in the Chapter II section entitled Development of the Attribute Scoring Procedures. The equations are repeated below, beginning with the attribute security, y_1 :

$$y_1 = \{ (1.0)(n_{air}) + (0.5)(n_{grd}) + (0.0)(n_{comm}) \} / n_{tot} \quad (3)$$

where

- n_{air} = number of trips using military or contract air transportation
- n_{grd} = number of trips using ground transportation
- n_{comm} = number of trips using commercial air transportation
- n_{tot} = total number of trips

The formula used to calculate the manpower utilization score, y_2 , was:

$$y_2 = (m_* - m_j) / (m_* - m^*) \quad (4)$$

where

- m_j = the manpower requirements for model being evaluated
- m^* = the "ideal", the lowest manpower requirements among the four models
- m_* = the "anti-ideal", the highest manpower requirements among the four models

The formula for scoring economy, y_3 , was:

$$y_3 = (n_{tot} - n_{air}) / n_{tot} \quad (5)$$

where

- n_{air} = the number of trips made using air transportation
- n_{tot} = the total number of trips made by all transportation modes

The formula used to calculate the score for y_4 , customer service, was:

$$y_4 = 1 - \{(a_{\text{tot}} - a_{\text{door}})/a_{\text{tot}}\} \quad (6)$$

where

a_{door} = the number of accounts serviced "door-to-door"

a_{tot} = the total number of accounts served by the model

Employing these formulas to assign a score to each attribute of every model gave the results listed in Table V. Included are the scores for the hypothetical ideal and anti-ideal alternatives.

Table V
Attribute Scores for Individual Models

	<u>Security</u>	<u>Manpower Utilization</u>	<u>Economy</u>	<u>Customer Service</u>
Model 1	0.616	0.180	0.622	0.052
Model 2	0.638	1.0	0.566	0.0
Model 3	0.631	0.547	0.588	0.050
Model 4	0.543	0.0	0.768	0.050
(Ideal	0.638	1.0	0.768	0.052)
(Anti-ideal	0.543	0.0	0.566	0.0)

These values formed the inputs for the application of the compromise programming procedure which is described in the next section.

Compromise Programming Results

By way of review, compromise programming is a technique which allows multiple areas of interest (goals, objectives, or criteria) to be considered when making complex decisions. The implicit assumption of compromise programming is that, by sacrificing a little in one or more areas of interest, other interests may benefit resulting in an alternative that is altogether more satisfying. The acceptability of an alternative is a function of how closely it emulates the hypothetical "ideal" alternative. By visualizing each alternative as a point in space, it becomes possible to measure the geometric distance between the point representing the ideal alternative and the points representing all other alternatives. The best alternative is the one which minimizes this distance. The concept of using distance as a proxy measure for human preference allows the adaptation of the Euclidian formula for computing distance between two points to determine the acceptability of various alternatives. Thus, the following compromise programming formula, normalized to prevent distortion of data, was developed:

$$d_p = \left[\sum_{i=1}^n \left\{ w_i (y_i^* - y_i) / (y_i^* - y_{\bullet i}) \right\}^p \right]^{1/p} \quad (2)$$

where

- d_p = the normalized distance
- y_i = the actual score for attribute y_i
- y_i^* = the "ideal", the best score for attribute y_i
- $y_{\bullet i}$ = the "anti-ideal", the worst score for attribute y_i
- w_i = subjective weight, or importance, assigned to attribute y_i
- p = subjective measure of the decision maker's decision policy
- n = the number of measures of attribute y_i

and where $w_i > 0$ and p ranges from 1 to ∞ .

As the formula suggests, this technique also has the capability to assign different weights, or measures of importance to the various criteria that are of interest to the decision maker. These weights must accurately reflect the concerns of the decision maker. The following attribute weights were recommended by LtCol Fisher, ARFCOS Director of Transportation (7):

Security, w_1	= 0.4
Manpower Utilization, w_2	= 0.3
Economy, w_3	= 0.2
Customer Service, w_4	= <u>0.1</u>
Total	= 1.0

Substituting the attribute scores given in Table V and the weights listed above into the compromise programming equation yields a final score for each model. These scores are listed in Table VI. Because the objective was to minimize the distance from the ideal alternative, the best alternative is the one with the lowest final score

Table VI
Compromise Programming Scores of Individual Models

	<u>Distance from Ideal</u>		
	<u>$p = 1$</u>	<u>$p = 2$</u>	<u>$p = \infty$</u>
Model 1	0.483	0.300	0.246
Model 2	0.300	0.224	0.200
Model 3	0.347	0.226	0.178
Model 4	0.704	0.500	0.400

Summary

Using the methodology as the road map which it represents, it has been possible to evaluate the models that were proposed in the beginning of this project. The results of this evaluation are not altogether surprising. The system which most closely emulated the ideal alternative was Model 2, the system which modeled the network using three instead of four or five stations. The reasons for Model 2's superiority are somewhat obvious in reflection. Less manpower is required to staff three stations than to staff four or five stations. The greater number of accounts being handled by San Diego required them to abandon door-to-door deliveries, and to make full use of consolidated control points and central servicing points. This procedure is much more efficient, although it does sacrifice part of customer service. However, there should be other ways to keep customers satisfied. Another reason for the success of the Model 2 was an increased reliance on aerial modes of transportation. In fact, the only drawback to using air transportation more often is the fact that it is more expensive than other modes of transportation. But the desire to optimize these conflicting goals of security, economy, efficient manpower utilization, and customer service is the very reason that compromise programming is such a promising management tool. When properly applied, it can assist the decision maker in making the most acceptable choice, and it provides a replicable record of the steps taken to reach the decision. Thus, the recommendations of this researcher are that ARFCOS consider the following suggestions.

First of all, ARFCOS managers should consider either reducing the responsibilities of the Los Angeles station or completely closing it down. The only major hub of air transportation that is readily available from that location is LAX International Airport, which leaves much to be desired from

a security point of view. Stations should have greater access to military air facilities in order to make better use of the greater intrinsic security of military or contract air transportation.

Second, existing stations and routes should be examined to ensure that managers are making full use of consolidated control points and central servicing points wherever and whenever possible. The procedure of making door-to-door deliveries may be attractive to the customer, but it greatly reduces the efficiency of daily operations. This level of customer service should be considered the exception rather than the rule.

Finally, the combined capabilities of computerized network simulation and compromise programming should be fully exploited to help in making future decisions regarding adjustments and changes to courier station operations.

IV. Conclusions and Recommendations

General Conclusions

Designing and evaluating distribution networks is truly a complicated balancing act. If ARFCOS expects to accomplish this feat, they should make full use of the latest and most capable management tools. Computer simulation and multiple criteria decision making techniques such as compromise programming are two such tools that seem eminently suitable to this and other management applications. Through the use of these tools, four models were developed, simulation runs were made, an analysis was performed, and an alternative was selected as the best of the four available systems. This by no means indicates that this model is the only acceptable alternative. But it does support the presence of certain attributes of more successful systems. Among those attributes are the commitment to improving the use of military or contract air transportation for making ARFCOS deliveries. Unfortunately, as a result of this increased use of aerial modes of transportation, customer service levels will likely go down. However, the efficient management of the most limiting resource, manpower, will almost assuredly increase. By using the technique of compromise programming to assist in the decision making process, managers can be assured that their decisions consider all areas of concern, and that they are sound, objective, and supportable.

Furthermore, the use of computer simulation allows managers to evaluate distribution systems for a fraction of the cost or danger of implementing policy blindly. Their use can easily have immediate payback in

terms of problems uncovered and solved before operations are impaired through the implementation of an unsatisfactory system.

Recommendations

As a result of the research of this thesis, the following recommendations are made to the managers of ARFCOS:

1. The Los Angeles ARFCOSTA is not adequate for its mission as it stands now. The station should either be closed down, moved, or have its volume curtailed. Preferable locations for future stations should be at or near military air bases to enable the station to make greater use of available air transportation and security forces.

2. Wherever practical, the use of aerial modes of transportation by couriers to serve customers should be encouraged. This will greatly improve efficient manpower utilization on all but the shortest routes.

3. Managers should consider the use of computer simulation and compromise programming as a method for evaluating potential changes to ARFCOS operations without excessive risk of failure or expense. The formulas developed within this thesis accomplish the goal of evaluating competing networks on multiple attributes, and these comparisons provide the necessary inputs that allow the compromise programming technique to work.

Final Comments

Implementation of the above suggestions are at the discretion of the commanders at ARFCOS. It should be noted, however, that the models developed in this research are static models. They do not change with time except through the intervention of the programmers and/or users.

ARFCOS, however, is not a static system. In fact, many changes have been

made that affect operations in the areas that this thesis modeled. This should not invalidate the results of this research. In fact, some of the changes being made are along the same lines as the recommendations made above. For instance, there is concern to standardize customer service and improve efficiency throughout ARFCOS by relying more heavily on the use of consolidated control points and central servicing points, and getting away from the door-to-door service many stations have provided in the past. Procedures are being developed to allow the use of air freight companies, such as United Parcel Service, to transport couriers and ARFCOS materials between ARFCOSTAs. These changes reflect a willingness to try new, innovative ideas, and this willingness may be the best hope for the future of good management, for it is this willingness that allows and encourages young managers to take an active interest in improving the status of operations worldwide.

Bibliography

1. Banks, Jerry and John S. Carson, II. Discrete-Event System Simulation. Englewood Cliffs NJ: Prentice-Hall, Inc, 1984.
2. Department of the Air Force. Armed Forces Courier Service Administration and Operations. AFR 183-2. Washington: Government Printing Office, 1 October 1982.
3. Department of the Air Force. Armed Forces Courier Service Charter. AFR 183-1. Washington: Government Printing Office, 15 July 1982.
4. Department of the Air Force. Armed Forces Courier Service Manual. Wright-Patterson AFB, ARFCOS station, 14 September 1984.
5. Fisher, Lt Col Larry, USAF. Director of Transportation, Armed Forces Courier Service, Ft. Meade MD. Telephone Conversation. 20 January 1986.
6. Fisher, Lt Col Larry, USAF. Director of Transportation, Armed Forces Courier Service, Ft. Meade MD. Personal Interview. 19-20 June 1986.
7. Fisher, Lt Col Larry, USAF. Director of Transportation, Armed Forces Courier Service, Ft. Meade MD. Telephone Conversation. 21 July 1986.
8. Pritsker, A. Alan B. Introduction to Simulation and SLAM II. New York: Halmsted Press, 1984.
9. Steward, Maj Douglas E. and Maj Winston D. Nelms. A SLAM Model of the Armed Forces Courier Service CONUS Stations: A Strategic Planning Tool. MS Thesis GLM/85S-75. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1985.
10. Shannon, Robert E. Systems Simulation: the Art and Science. Englewood Cliffs NJ: Prentice-Hall, Inc., 1975.
11. Zeleny, Milan. Multiple Criteria Decision Making. New York NY: McGraw-Hill Book Company, 1982.

VITA

Major Dwight G. Corbett was born in Goldsboro, North Carolina on November 3, 1951. He graduated from Fuquay Springs High School and entered the United States Air Force Academy in 1970. In 1974, he graduated from the Academy, receiving his commission and a Bachelor of Sciences degree in Life Sciences (Pre-Medicine). He earned his Pilot wings in 1975 at Moody AFB, Georgia, and was then assigned to the 96th Bomb Wing at Dyess AFB, Texas as a KC-135A copilot. After upgrading to Aircraft Commander, he was selected for an Air Staff Training (ASTRA) assignment as an operational readiness inspector with the Air Force Inspection and Safety Center at Norton AFB, California. His next assignment was with the 97th Bomb Wing at Blytheville AFB, Arkansas, where he served as a B-52G Aircraft Commander and a Wing Command Post Emergency Actions Controller until May 1985, when he entered the School of Logistics and Supply at the Air Force Institute of Technology.

Permanent address: Route 1, Box 423

Fuquay-Varina, North Carolina 27526

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

10-AL74575

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS						
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited						
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE									
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFIT/GLM/ENS/86S-12			5. MONITORING ORGANIZATION REPORT NUMBER(S)						
6a. NAME OF PERFORMING ORGANIZATION School of Systems and Logistics		6b. OFFICE SYMBOL (If applicable) AFIT/ENS		7a. NAME OF MONITORING ORGANIZATION					
6c. ADDRESS (City, State and ZIP Code) Air Force Institute of Technology Wright-Patterson AFB, OH 45433-6583				7b. ADDRESS (City, State and ZIP Code)					
8a. NAME OF FUNDING/SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (If applicable)		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER					
8c. ADDRESS (City, State and ZIP Code)				10. SOURCE OF FUNDING NOS					
				<table border="1"> <tr> <td>PROGRAM ELEMENT NO.</td> <td>PROJECT NO.</td> <td>TASK NO.</td> <td>WORK UNIT NO.</td> </tr> </table>		PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.						
11. TITLE (Include Security Classification) See Box)									
12. PERSONAL AUTHOR(S) Dwight G. Corbett, Major, USAF									
13a. TYPE OF REPORT MS Thesis		13b. TIME COVERED FROM _____ TO _____		14. DATE OF REPORT (Yr., Mo., Day) 1986 September					
15. PAGE COUNT 56									
16. SUPPLEMENTARY NOTATION									
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)						
FIELD	GROUP	SUB GR.							
12	02		Decision Theory, Decision Making, Networks, Computerized Simulation						
19. ABSTRACT (Continue on reverse if necessary and identify by block number)									
<p>Title: COMPROMISE PROGRAMMING WITHIN ARFCOS: SELECTING AN OPTIMAL DISTRIBUTION NETWORK FOR THE SOUTHWEST</p> <p>Advisor: Major William Rowell Assistant Professor of Operations Research</p> <p style="text-align: right;"> <i>Approved for public release: LAW AFR 150-17</i> <i>LYNN E. WOLFE</i> <i>215415</i> <i>Dated for Research and Professional Development</i> <i>Air Force Institute of Technology (AFIT)</i> <i>Wright-Patterson AFB OH 45433</i> </p>									
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS <input type="checkbox"/>			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED						
22a. NAME OF RESPONSIBLE INDIVIDUAL Major William Rowell			22b. TELEPHONE NUMBER (Include Area Code) (513)255-3362		22c. OFFICE SYMBOL AFIT/ENS				

The Armed Forces Courier Service (ARFCOS) is the military's distribution network for classified materials. ARFCOS considers available manpower as more binding on future operations than available funding. Therefore, the efficiency of present operations must be improved to reduce manpower requirements while maintaining or improving mission effectiveness. Currently, managers have no specific tools for analyzing alternative distribution networks and comparing them to current systems.

This thesis identified the Southwest as a region in ARFCOS's CONUS operation that would most benefit from this type of comparative analysis. A methodology was proposed using principles of computer simulation and a multiple criteria decision making technique called compromise programming. Models of four alternative distribution networks were built using SLAM II as the implementing language. Simulations were run on a VAX 11/785. All results were compared on the basis of security, manpower utilization, economy, and customer service. Then the best network was identified through the application of compromise programming.

This research resulted in the following recommendations. First, current operations by the stations serving the Southwest should be modified to reduce or eliminate the responsibilities of the station at Los Angeles AFS. Next, ARFCOS routes should be examined to ensure maximum use of Consolidated Control Points and Central Servicing Points wherever possible. Finally, the combined capabilities of computerized network simulation and compromise programming should be fully exploited to enable managers to make sound, supportable evaluations of alternative distribution networks with minimum risk or cost.

END

12-86

DTIC